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ABSTRACT

The essential characteristics of a system for providing education to students not present in the same classroom as the instructor are two-way voice contact, availability where the students are, and the capacity to transmit still pictures. This suggests the use of slow-scan televideo (SSTV) which is able to be accommodated by voice-grade telephone circuits, though it does require some method of signal-storage at the receiver. Compared to other methods, such a system would be economical, and trial of SSTV at Motorola's Research Center suggests that it is acceptable to students. Development of hardware based on digital solid-state memory will make mass production of the storage devices more feasible, as will the development of microprocessors. Barriers to overcome before SSTV will become widespread include familiarizing the public with the possibilities of SSTV, attracting private industry, and determining the effect of wide-spread use of SSTV on the telephone system. (WBC)

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EXTENDING THE REACH OF THE UNIVERSITY WITH NARROW-BAND TELECOMMUNICATIONS: The Present and Potential Uses of Slow-Scan Televideo for Continuing, Off-Campus Education

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ABSTRACT

We discuss various means of providing education to students not present in the same classroom as the instructor. We specialize to modes of communication which permit maximum flexibility for reasons of convenience and cost. In particular, we look at systems which use the ordinary telephone network. The particular technology which is of direct concern is called slow-scan televideo, which permits transmission of stationary visual information over telephone lines (or their equivalents) with displays on ordinary television receivers.

INTRODUCTION

Extending the reach of the university is an obvious desideratum which requires no extensive justification here. Suffice it to say that we are interested in providing a needed service to people for whom it is not convenient to come to campus. At the same time, we are interested in assisting financially-pressed colleges and universities to extend their market, share and make more efficient use of their existing resources. We shall arbitrarily restrict our discussion to the area of "continuing (off-campus) education" directed at adult groups such as teachers, doctors, nurses, lawyers, engineers, management personnel, military personnel, inmates of institutions etc.

The population we are considering is both more narrow in its desires and yet more demanding in some ways than the resident on-campus student group a university usually deals with. The "atmosphere" of a university ambience is less important to this group either because they have already experienced it or because they have determined that they cannot afford it. This population

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is circumscribed in time and space. They have other responsibilities and pressures on them and they want to learn. Their personal motivation may be high but they require "service". They are frequently ready for intense periods of study but these must come at times and in amounts compatible with their lives as non-students. They are mature individuals with much experience of their own to share with their fellow students (and with the faculty). They may understand the benefits of leisurely self-study but cannot afford the time and require as much help as a teacher (and their fellow students) can give them: to evaluate their preparation, to organize the material in a manner appropriate to their background, to motivate their learning, to maintain their interest and momentum and provide discipline (and relief from unnecessary frustration) by asking and answering questions, and to provide a measure of their progress. Not least of all, some certification of their success is frequently desired (a grade, certificate or degree credit).

A MODEL OF AN EDUCATIONAL EXPERIENCE AND WHAT IS AVAILABLE

We are coming to the point of deciding what we would like to provide for continuing education. The model of a professor and a class of about 25 students is a good one. The essence of the situation is the INTERACTIVE RELATIONSHIP between the teacher and the students and, especially for the mature population we are concerned with, among the students. We have a variety of old and new technologies to provide information : books, correspondence courses, programmed texts, audio-cassette lectures, audio-cassette-with-slide lectures, sound motion pictures, broadcast radio and TV lectures, video tape presentations, videodiscs etc. It is the element of INTERACTION, however, which transforms the transfer of information into the process of instruction.

We leave to others the discussion of the logistical and organizational details of physically transporting professors and students to off-campus locations. We are here interested in the use of "media". we are especially concerned with the use of media to "bring" an instructor (and students) at one location into interactive contact with students at another location.

Media

Since the popular use of the term "media" encompasses both "canned"systems and interactive ones, we must draw some distinctions between them in order to be able to discuss the various implications of the changes which new technology has wrought.

Informational or recording media represent ways to store and present information to the student. Telecommunications media or telemedia involve essentially instantaneous transmission from one place to another. For the purposes of our discussion, a telecommunications medium is a real-time system which is basically interactive and it is the interactive feature which dominates and defines the distinction. Thus, a lecture broadcast to a mass audience which cannot immediately respond to or affect the course of the lecture might just as well be recorded and distributed, for the purposes of our distinction. The use of videotape in almost destroying the old distinction between "live" and "recorded" broadcast television is a case in point.

Among the operating parameters of informational media which have been changed by new technology are such things as: information density, rate of information transfer, reinforcement capability, review capability, cost and ease of preparation of materials For example, a book is an information medium capable of very dense information storage It can correlate text and pictures but it cannot correlate sight and sound. Also, a student is limited by the rate he or she can read or, more properly, study the material Visually-oriented students find books to be very effective and many can assimilate material most rapidly by reading it. Aurally-oriented students are sometimes better served by audio-cassettes; the rate at which information is presented might also be better for them. Both kinds of student might be better off with a videotaped lecture. The combination of both visual and aural material serves to reinforce and enhance the student's assimilation and retention of it. The advent of videodiscs promises to do this at lower cost than heretofore and with capital equipment which might be widely available as a consumer item All of these are informational media, however since the writer or lecturer cannot adapt his (fixed)

presentation to the specific needs of the individual student. Depending on the economics of publishing and videotape production, the writer or lecturer must address a large audience, frequently not smaller than a few thousand. The nature of the economies of the videodisc indicates that this will be true to as great an extent: the merits lie in the economies of mass production of identical units and it will be largely as a medium for entertainment that the system will be justified and priced.

Educational technology

We are very cognizant and appreciative of the new opportunities and possibilities which advances in informational media have made available to education We shall espouse the thesis, however, that these systems (i e new informational media, such as the videodisc) affect all of education and do not address the problems of continuing off-campus education particularly In fact, we might expect that they should affect the provision of continuing off-campus education less than other forms of education because of the capital equipment required. We would always hope to minimize the capital equipment required at an off-campus site. In any case, we take it as obvious that all educational situations should utilize whatever is available: books, prepared lecture notes, slides etc.

It is sometimes surprising to think how small was the initial impact of the invention of printing and the book on the nature of universities and the lecture-demonstration system (or, how slow has been the academic profession to respond). We believe that the impact of educational technology on the teaching process has been relatively slow in coming because of several factors. Certainly, there is the basic conservatism of the educational profession and, inherent in this, the "software problem": how to assimilate customary methods of preparation and presentation into the new formats Perhaps most important, the centrality of the teacher's role -- in organizing, pointing, easing the way and monitoring the student's progress through a mass of information --is not changed drastically by the format of the information.

We do not see the new educational technology pertaining to informational media providing a panacea for the problems of continuing, off-campus education. In fact, we do not even see media, which are oriented to preparation by professionals of a superior product which is geared to a large market (for example. an outstanding lecture-demonstration by an eminent professor) even addressing the basic problem: providing the individual student off-campus with the ability to interact with a teacher

The model

We have now argued ourselves into a set of criteria. We wish to provide the essence of what has traditionally been available on campus to students who are off-campus. Further, we wish to do this in ways which do not require large perturbations in the procedures familiar to both professors and students. The essence certainly includes the ability to interact; this means two-way voice contact is an absolute necessity. We take as our model of the classroom one in which the professor communicates via an overhead projector. Harking back to the blackboard is too retrograde a step' Scientific conferences have almost totally eschewed the blackboard in favor of the overhead projector (and slides) and the trend is the same in the classroom. One has at least part of the armamentarium of visual aids available today: the ability to write in real time (as with a blackboard) but also the ability to pre-prepare material, use typewritten material, graphical aids and pictures.

We also make two assumptions Using our model, one is quite good: motion is not needed in the classroom for presenting information The second is more arguable: motion is not needed for information transfer in that the affective interaction between professor and student is not important in the teaching situation. This assumption is certainly more plausible in the situation of advanced university-level courses and mature, continuing education students. We believe. in general, that information transfer alone (with the necessary intellectual interaction to make instruction occur) does not require motion Motion is generally required only when it is desired to elicit an emotional response In the classroom, it is

only those rare peculiarly animated and stimulating professors with a unique teaching style who do much of their job requiring motion. For the vast majority, one is as often likely to observe a professor's "tic" as his animation and, so, the ability to see him "move" may be obviated

System definition

We are now at the point of defining a system to provide off-campus education (with the instructor temporally but not spatially present) It must be interactive with two-way voice (as in a classroom); it should provide the ability to display visuals, both pre-prepared and constructed in real-time in response to questions or a perceived need (as in a classroom with an overhead projector). It need not, however, display motion (again, as in most classrooms) It should be available wherever the students are and, ideally, it should be possible to teach students who are not all in one place. Further, to help educational "productivity", it would be desirable to load on-campus classes incrementally with students from their off-campus locations. We have in mind that the total number of students, both on- and off-campus, would be less than 50 and, preferably, about 25 This is to foster interaction which declines with both too few and too many students.

We are clearly aiming at a system which can use the ordinary telephone network to transmit still pictures and two-way voice. Television pictures are familiar and acceptable to almost everyone and suggest the television set as the display of choice Telephones and television sets are in fact, ubiquitous and the existing 1/8 BILLION telephones in the U S. (and the 1/4 BILLION in the world) are in place. reliable and interconnectible We aim for a system which can telecommunicate between any two points which are connected by an ordinary voice-grade telephone line. If all our transmissions (both audio and visual) can be sent over ordinary telephone lines, we recognize that conference-call features, high fidelity gear and audio recording equipment already available at consumer-type prices become instantly adaptable to our audio-visual telecommunications system

Slow-scan televideo

A technique exists to provide what we want. We use "televideo" to distinguish it from "television": televideo implies the remote telecommunication of still pictures whereas ordinary television conveys motion and the thirty-frame-per-second picture rate is designed to provide the verisimilitude of motion

A simple argument suffices to show that televideo can be used over ordinary telephone lines A communications channel is able to carry information in much the same way that a pipe is able to carry water. The carrying capacity of a communications channel is measured by its "bandwidth": the range of frequencies which it can transmit without substantial distortion and loss. The unit of frequency is the "hertz" which is equivalent to the older unit, "cycles per second". A voice-grade telephone circuit has very approximately a bandwidth of about 4.5 KHz (where we denote"thousands of hertz" by "KHz"). That is, it carries only audio frequencies. We may call this a "narrow-band channel". An FM-radio channel, similarly, is also "narrow", being about 15 KHz wide. A black-and-white TV channel, on the other hand, transmits thirty frames per second and requires a bandwidth (provided by the FCC for the broadcast band or by the owner of a coaxial

cable, which can carry between 20 and 40 such channels) of about 4.5 MHz ("millions of hertz"). This may be called a "broadband channel". Speaking roughly, a full television picture (with motion) requires the equivalent of about one thousand voice-grade telephone telephone channels. Bell's Picturephone is no help in this regard, being a low-resolution television system which requires about 300 voice-grade equivalents. We stress the well-known fact that Bell's Picturephone cannot be transmitted over ordinary telephone circuits being intrinsically a 1-MHz system. Suppose, however, that we do not send 30 frames per second but, rather, only one new picture in 33 seconds. We thus see that the information rate goes down by the product of 30 X 33, or almost 1000. This (lower) rate can, indeed, be accommodated by an ordinary voice-grade telephone circuit. All we have had to give up was the ability to transmit motion and our ability to change pictures more often than once every 33 seconds.

Actually, we can get by in most circumstances with a picture whose resolution may be less than that of a TV picture and this lower-resolution picture may be transmitted proportionately faster. (A still picture of Picturephone-type resolution could be transmitted in about 8 seconds.) On the other hand, a picture which we should like to be of higher resolution than ordinary TV can be transmitted in proportionately more time. This actually provides a flexibility which an ordinary television channel does not have.

This is why we have emphasized that, in most classrooms, the visual display does not change very rapidly. If we use our model of an overhead projector, in which the display does not change more often than once every 33 seconds, we see that we can use ordinary telephone lines. This is more than adequate in most educational situations

We may ask why this technique has not already been used widely since people have been trying to squeeze pictures through telephone channels since the beginning of the telephone (and telegraph). Variations of the basic idea in fact, have been in use. However, some new technological developments have made this technique feasible and attractive only within the recent past These pertain both to the wide acceptance of the television-display and the development of "memory systems" for storing the large amount of

information contained in a picture. Whereas in a television picture, the information is essentially stored in the channel, in that it is used as fast as it is transmitted, the "slow-scan" (actually "controlled-scan" is better) part of the description implies that the picture is sent piece-by-piece over the narrow-band channel which means that the pieces must be stored at the receiver end and, when the picture is complete, displayed. The analogy is to filling a water reservoir with a trickle of water from a thin hose. When the reservoir is full, the water may all be dumped out at a high rate. At the receiver end, the memory unit must serve several purposes: it must accept the picture information at a "slow"rate characteristic of the telephone line; it must accumulate and store this information in the proper sequence until the picture is complete; it must then spew the information out rapidly (at video rates) to a television set so as to maintain a flicker-free (but stationary) picture on the TV set. Memories which have been used to this end include a slowly-decaying phosphor (as on a radar screen), video discs, scan converter storage tubes, and digital computer memories. It is now possible to build a "box", with no moving or glass parts (i.e. completely "solid-state") about the size of a breadbox, which connects an ordinary telephone to an ordinary TV set. This box is portable, would be maintenance-free and, in a volume of about 10,000 units, available at the cost of a consumer appliance, that is, a few hundred dollars.

What else is available for comparison

Interactive educational television systems exist with ordinary TV broadcast from a central transmitter to various locations with audio feedback from the remote students using telephone or FM radio. These systems (e.g. Stanford, USC) are successful and effective when paid for but they entail large initial capital investment (e.g. $600,000 for a system considered by a consortium of Northwestern, IIT and Circle Campus for the Chicago area). Moreoever, they have a finite range due to FCC limitations on the power of an educational TV station. The locations (typically industrial sites)which can receive the transmissions require special antennas and must be geographically proximate to the transmitter (about 40 miles, maximum) although

the area served can be stretched in one dimension (i.e. the service area need not be circular). Also, one TV station can only transmit one class at a time. The question is whether the single feature of motion is worth these disadvantages (We might also mention at this point the possibility of time-sharing such a TV station using SSTV: potentially 300 SSTV transmissions could be sent simultaneously and independently received with the same TV channel allocation)

Other systems exist for sending visual information over narrow-band channels such as telephones. These have been reviewed by us elsewhere[1] but include teletype, facsimile and telewriting (also called telescript) systems such as Victor's VER3 and the Bell System's Remote Blackboard The telewriting systems have been adapted to education with the most recent such device, Bell's current version of its Remote Blackboard, being tested by the University of Illinois We would argue that the model of a blackboard, rather than that of an overhead projector, is a retrograde position to take. The flexibility of format and pictorial capability which a TV camera permits, as well as the full range of TV studio technology, makes it fairly convincing that the SSTV approach is to be preferred. The fact that Bell's current Remote Blackboard is displayed on a TV monitor at the receiving location argues for these various systems to converge and the SSTV technique to include the capabilities of the others as a subset.

SLOW-SCAN TELEVIDEO DIRECTIONS

We recognize that there are two parallel developments which must take place: the various contexts in which SSTV may be used must be tried and analysis made of what accommodations are required by a new medium; at the same time, equipment development must proceed to improve reliability, lower costs and provide features which appear to be desirable.

We must emphasize that we are dealing with a general telecommunications technique with applicability in fields related to, but independent of, education. We have reference to general teleconferencing, provision of medical services and the general substitution of telecommunications for travel by people. We have only to look at the glowing predictions for the various social uses of interactive (broadband) cable systems which abound in the professional literature and the public press. Our thesis is that almost all of the non-entertainment functions of interactive cable systems can be provided today, using the existing, presently-installed "cable" system with potentially 125,000,000 interconnected terminals.

This claim is really not surprising. The telephone by itself permits an enormous amount of substitution for personal travel (for business purposes, i.e. not purely social). This, of course, is because people communicate primarily aurally. However, a visual dimension does exist. It has been estimated that an "ordinary" (humanistically-oriented) conversation between people in the same place is 95% aural while a "technical" or scientific conversation is still 85% aural. The provision of a visual capability is clearly of greater importance in the latter context. It does not require detailed study to note the differences in the use of classroom visuals among, say, English, History, Mathematics, Chemistry,and Art History.

Developing the use of a telecommunications technique (system) for a variety of applications benefits each one. The reasons are largely economic: more uses make it easier to justify the initial cost (both in dollars and in time for accommodation); more uses mean more users which implies economies of scale in production

and more people to communicate with. One cannot emphasize too strongly the last point with respect to a communications device: the first person to have a telephone had no-one to talk to, the second person had one, the third person made three conversations possible plus a conference, and so on. For all these reasons, we shall keep all SSTV uses and applications in mind, although education is our primary focus here.

We think ultimately in terms of an SSTV capability available to every household with a telephone. This may not be the millenium, but it would certainly carry the concept of continuing off-campus education to its theoretical limit. Perhaps strange to say, we think this is possible technically and economically, and even desirable absolutely, since the very limitations of the system insure against abuses of privacy and civil liberties. We point out for completeness that SSTV is completely upward-compatible with any broadband cable system which achieves wide distribution.

SSTV in education

We probably need not point out that telephones have long been in wide use in education. Education for students in remote areas has been provided by voice-only transmission over telephone lines or radio. Various telephone companies provide voice-only links between teachers and home-bound students and the Bell System offers a Teleclass Conference System for this purpose. The University of Wisconsin Extension Service, among others, has a statewide network of telephone terminals for courses and lectures. Despite the inherent frequency limitations of the telephone net, a professor at Northwestern's School of Music effectively lectured on piano-teaching technique (with music) from her apartment in Evanston, Illinois to about 200 piano teachers spread around the State of Wisconsin. We note that all of these programs and facilities are easily adaptable to SSTV (since the video transmissions use only audio tones).

We have already referred to the use of other narrow-band visual systems such as telewriting (VERB and Remote Blackboard). SSTV, using equipment made by Colorado Video Inc., has been tested

in schools in South Bend, Indiana, using an FM broadcast mode of operation in which several schools are linked to a central facility. Likewise, the Michigan Department of Education undertook a study using a subchannel of an FM station with a bandwidth of 12 KHz which permitted a TV frame (of lower resolution than standard TV) to be transmitted in 7.5 seconds. The results of this study were that "students at the grade six level learn as well from instructional programs displayed on Controlled-Scan TV as they do from programs displayed on regular TV." At the college level, Colorado State University ran a course via SSTV between two campuses separated by 100 miles and connected only by telephone lines.

We believe that continuing education at the university level and SSTV are well-matched to each other and that this is especially true for advanced scientific and engineering courses. As mentioned earlier, these typically have a higher-than-average visual content, change in the various fields is rapid which creates a need for continuing education of professionals, the need for interaction with a teacher-expert is more obvious in such subjects, and universities typically have problems with the teacher-to-student ratio being too small when resident students alone are counted. SSTV provides the possibility of incrementally loading classes with students from off-campus locations and, also, sharing courses between institutions.

We may distinguish different modes of operation depending on the function to be served. The economics and technical requirements are somewhat different at present although the "millennial system" will be able to serve all purposes. We emphasize again that all terminals must be essentially equal in their ability to interact forward and back by voice. This "aural democracy" does not necessarily extend to transmission of visual information. In a classroom, it is common for students to ask questions and make comments but relatively rare for a student to seize the chalk (or whip out a transparency for the overhead projector) and make a visual presentation of his own. Likewise, for many conferences there is a lecturer or presenter who has visual tools conveniently available to him but not (to the same extent) to his audience although, aurally, they are all more equal. A conference among equals, however, implies equality of opportunity for presentation of both

aural and visual material.

Symbolically, we may denote the various situations (for visual transmissions) by the notation

(visual sources) $\longrightarrow$ (receivers)

We may distinguish further on the basis of how many people are at each receiver terminal (an important factor in assessing the cost-effectiveness of the terminal) but we don't wish to get too involved in the symbolism. For example, $1 \longrightarrow n$ is a situation where a professor at a university is lecturing to students at n locations. A teleconference among equals might be denoted $n \rightleftarrows n$, a two-way interaction between scientists would be $1 \rightleftarrows 1$, while a seminar among professors at n_1 locations and "attended" by students at n_2 locations would be $n_1 \longrightarrow (n_1 + n_2)$

We have introduced this concept to point up the fact that not all situations require a full "transceiver" capability (ability to both send and receive visual information) and that a "receive-only" terminal is suitable for many student situations. We wish further to emphasize that the full spectrum of interconnect possibilities presently available with ordinary telephones are also presently available with SSTV but not yet with interactive cable systems or, even, Bell's Picturephone in those few localities where any service at all is available. The number of receivers and the number of persons at each terminal location also determine how economical in the sense of cost-effectiveness the available equipment is at any given time. Clearly, if thirty students are to use a receiver terminal as a class, it is easier to justify the system than would be the case where the students are in six different locations requiring a terminal for each five students on average. We repeat again our conviction that it will be possible to justify SSTV on a 1-person-per-terminal basis at some point in time.

The economics of teleteaching indicates that, at present, one must think of n students at each receiving location. To be concrete, we may focus on the provision of continuing engineering education to professional engineers employed in industrial locations. This should not be taken to circumscribe the utility of SSTV in education but a clear market has been demonstrated, the scientific-technical need for visuals exists, the time-saving element in travel is important (companies typically value their engineers' time at upwards of $25/hour) and there is some successful history of operation with interactive television (ITV) in this situation (e.g. Stanford and USC). The Stanford and USC operations are described elsewhere[2] but the situation essentially is that telecasts (within the range determined by the 10 watts/channel power limitation) are made to a number of industrial locations with the initial capital investment having been funded by NSF and foundation monies.

Stanford charges industrial students approximately double tuition for the extra expenses of running classes in the ITV manner. They have had a history of success in that they have had "customers" at the price and the "service" appears to have been satisfactory. The actual charges are not clearly meaningful or generalizable since it is not certain how the capital costs have been amortized. Also, Stanford's overhead on government grants is different from that of other universities and we do not know how to scale the figures. We can, however, estimate the differences in the capital costs for both the central installation and the industrial locations. The actual tuition surcharge required (if any) depends in detail on how one allocates the cost of the various "people" expenses in running an academic program and we shall not attempt to get into this complex area in this discussion. We do, however, believe that the operating staff should be much smaller for the simpler SSTV network than for the ITV system.

For an ITV system, we estimate that the system engineering and installation at the central facility amount to an initial investment of about $100,000. The studio-classroom costs about $150,000, the master control equipment costs about $125,000 and the antenna and transmitter about the same ($125,000). The total of about $500,000 compares with about $25,000. for system engineering and installation of SSTV equipment, about $25,000 for studio-classroom

equipment, about $25,000 for master control equipment (mostly standard teleconferencing and switchboard equipment available from a telephone company) for a total of about $75,000. This latter estimate is highly speculative since we shall discuss some experiments which involved a capital outlay for the studio-classroom of about $500. and which resulted in effective teaching. Assuming some operation of Parkinson's Laws in both ITV and SSTV situations (the former having presumably already occurred and the latter, perhaps, to be expected), we compromise at the $500,000. and $75,000 figures. The remote locations for ITV involve an expenditure of $2000 for the antenna and "down-converter", $1000. for the TV Monitor and telephones and $1000. for installation, or a total of $4000. Depending on what equipment we use for the SSTV case, the costs for the individual locations may vary significantly. At their initial price, RCA Videovoice equipment sold for $10,000. per transceiver terminal so that we might expect a total cost of about $11,000 per installation. (This would, incidentally, provide a transceiver capability. Colorado Video equipment was priced at about the same for a transceiver but the equipment "divides" into transmitter and receiver so that roughly 1/3 to 1/2 could be saved on a "receive-only" installation. Our ultimate expectation for a receive-only unit with additional features is a few hundred dollars.) SSTV for the RCA case is relatively more favorable with fewer remote locations on line which we believe would be the initial situation. However, the RCA transceiver price per location is higher than for an ITV receive-only location. We hope, of course, eventually to use a receive-only system at each remote location which will cost only a fraction of the ITV location cost.

SSTV technique and effectiveness

At Northwestern University, we have experimented with teaching via SSTV using primarily RCA Videovoice equipment and these experiments are more thoroughly described elsewhere[3]. Likewise, the equipment currently available is described elsewhere[1] but we may summarize the system used RCA Videovoice provides a transceiver capability at each terminal with full TV resolution possible (nominally 525 lines but actually about 340 lines, as is the case for home TV) with a transmission time of 60 seconds. Another option is

a "freeze-frame" mode, which stops any movement much as a snapshot does and which has half the vertical resolution but may be transmitted in 30 seconds During a transmission, the screen at both the transmitter end and the receiver end goes blank. This is an unfortunate feature of the system design which is a function of RCA's use of a scan-converter storage tube as the memory element which cannot both read and write at the same time. Colorado Video's equipment,based on a video disc,has somewhat inferior resolution and transmission-time features but "paints" the new picture over the old one in vertical strips moving from left to right. The LANTEL (Los Alamos - Northwestern TELevideo) System prototype paints the new picture on top of the old one in horizontal stripes from the top down. The blanking feature of the RCA system was modified by us in a later experiment in a way which should be done in more ideal systems

The gray scale and resolutions were compatible with usual home TV standards and were more than adequate for the purposes of teaching courses in physics and chemical engineering. Our standard mode quickly became the 30-second, frozen-frame, half-resolution transmission. Lower resolution yet and two-level gray scale (instead of the full gray scale of about sixteen levels) would have sufficed for most of our classroom transmissions of a mathematical nature.

The first concern was how to bridge the 30-second "gap". This was easily done by "talking" and making a special effort to "interact" with the students during the deadtime. This was, of course, possible because of our use of two telephone lines for all these tests: one for audio, the other for video. This is, in fact, not necessary since the video channel is not in use much of the time. It is technically possible to "time-share" the audio channel for the occasional video uses in such a way that the student is not aware of the "gaps". This has not yet been implemented in an SSTV system but the technology is straightforward if non-trivial to provide this "voice-over-video" capability for one telephone line. This is part of our ultimate desideratum of a one-unit-per-person system for students in their individual homes.

During the transmission time, discussion was continued about the pictured which had been displayed and was initiated about the picture in the process of being transmitted.

Despite this straightforward solution, which was operationally satisfactory during our on-campus experiments, there is a technical one which was implemented during a four-week experiment in which a course in Human Factors Engineering was taught during 12 lunch hours by a professor at Northwestern in Evanston, Illinois to students at Motorola's Research Center in Schaumburg, Illinois about 25 miles away. During the on-campus experiments, we determined that the 30-second delay in the visual transmission was acceptable to the student if the teacher accommodated to the medium by using verbal discussion to finish a previous point or to prepare the student for the next transmitted visual. Nevertheless, students indicated that they would like to see the last frame of video retained. That is, there is merit to having both the current picture and the one just previous This advance in the system technology requires additional memory Because we project memory to become increasingly economical in the future, we decided to add this feature for the Motorola demonstration on an ad hoc basis We added additional memory at the receiver end in the form of an Hitachi Disc with appropriate switching.

The system at the remote classroom receiver now had two display monitors, one for "current video" and one for "previous frame". It is possible to operate the memories and displays as follows: at initiation of a new video transmission, both displays are switched to observe the most recent previous frame (for the RCA system, this obviates the annoyance of the screen going blank); upon receipt of the full frame into the primary memory, the primary display is switched to observe the new frame upon teacher command or when the frame is complete

There are several advantages to this specification. Most important, the teacher is able to present lecture material without the student necessarily realizing the existence of a finite video transmission time. All that is required is that the teacher know what is to be transmitted 30 seconds before it is to be shown.

The transmission occurs sub rosa and the new frame "appears" instantly (in 1/30 second). The only circumstance where the student would notice the delay is in response to a specific question or in a clumsy teacher presentation In any case, the acceptability of the delay has been established An additional advantage,which came out during our field test, was the instructor's ability to transmit two video frames, when desired, and talk about both simultaneously (although they were actually transmitted sequentially).

One need came to the fore almost immediately in actual usage: the absolute requirement for quality audio. Since the prime mode of interacting is aural, it is important that audio quality be maximized This is true both for the students' ability to hear the professor and the professor's ability to hear the students (and the students' ability to hear each other if they are in different locations). We quickly adopted the use of lavalier microphones for the professor, Bell System Model 50A Portable Conference Sets for both studio- and remote-classrooms, and voice-actuated microphones with constant-level controls.

Concern about the need for a professor to make great perturbations in his teaching style in accommodating to the SSTV format was alleviated during the Motorola test. The instructor was a brilliant teacher but one who held no special brief for this sort of media teaching. Accordingly, he pushed the medium very hard with little attempt at accommodation to its possible limitations. Lectures were not carefully prepared, he used figures from thick books, scribbled on cards during the lecture for transmission in response to questions (and, indeed, as part of the main lecture) and mixed drawings of different sizes and aspect ratios. At times, the lectures were mostly aural, necessitating pictorials of the professor rather than course-related material to "fill the gaps". The student-camera-operator was more than equal to the task (using a zoom lens on the TV camera) and both the medium and the last-frame feature came through the test successfully.

Even before the last lecture, the Training Director of Motorola "accepted" the medium. That is, Motorola was willing to pay tuition for degree programs if Northwestern's Technological Institute could

deliver the course material largely by SSTV. During the last period, a crude student "evaluation" was done. Most significant is the following:

1) More than 80% of the students felt that they had learned as much in the SSTV lectures as they would have in the same time spent in a live lecture.

2) 90% strongly preferred to be able to stay in the plant to take the course.

3) Over 70% thought the last-frame feature was an important addition.

4) 90% of the class was satisfied with the tonal quality of the telephone audio.

5) 90% said that the video picture helped to direct and focus their attention for enhanced learning, even when the picture was not absolutely essential for the presentation. Video tapes of the remote classroom situation show students asking questions of the (still) monitor as if it were the professor (even when the monitor was showing a still picture of something other than the professor).

6) 60% would pay tuition money themselves to receive courses by this medium.

7) The members of the class were split as to whether they thought motion was necessary We think this was not due to the demands of the course but, rather , to the erroneous preconception of the class that they would be seeing CCTV!

8) The class was not entirely comfortable with SSTV. About half said they "didn't like it" but couldn't pinpoint why.

We think the individual student evaluations supported the medium. In the design of this minicourse, the students never met the instructor in person; they were not prepared for the medium (most expecting CCTV); they participated voluntarily, on their own time, and without formal course credit. Perhaps most significant of all, almost every student stayed with the class sessions from the first to the last one.

We should stress that courses taught by any medium should be carefully prepared and should utilize whatever is possible in the way of pre-prepared material to be handed out in advance of the class: lecture notes, books, problems, pictures, etc. It is the "real-time" aspect of classes which the medium provides. Media teaching points out most forcefully the stupidity of much classroom

technique, wherein teachers copy material from their notes onto a blackboard from which students dutifully copy the material into their notebooks without too much thought intervening. Media teaching points up the fact that classroom time is precious and should not be spent on secretarialfunctions. Media teaching of this sort is good experience for any teacher in improving and understanding classroom technique. Compared with ITV, SSTV has an additional advantage which came out during interviews with individual faculty members who were exposed to the system. Many faculty people are not partial to TV teaching because they feel exposed and ill-at-ease before the camera's all-seeing eye. SSTV severely delimits this "invasion of the classroom" and should be easier for many faculty members to adjust to than ordinary CCTV.

Hardware development

The presently-available commercial SSTV systems (RCA Videovoice, Colorado Video, Infotech) are cost-effective only for n students per location with n reasonably large. In order to extend the benefits of SSTV to areas of continuing education with lesser student-density (ultimately aiming at a density of one per terminal) the cost must be reduced, maintenance problems alleviated and portability and installation facilitated. Ideally, the voice-over-video capability should be provided to permit effective use of a single telephone line (the picture would, for example, be sent in pieces during the natural pauses in human speech). In addition, other features should be provided, always keeping in mind the ultimate goal of a small, reliable, consumer device in the range of a few hundred dollars.

E-Division of Los Alamos Scientific Laboratory and Northwestern University have been collaborating on the development of a version of SSTV hardware based on digital, computer-type solid-state memory The significance of this development is manifold:

1) The use of computer solid-state memory permits the system to be rugged, reliable, compact and low in power consumption. Most important of all, it enables the development to participate in the continuing decline in the cost and size of memory useful in the computer industry It was anticipated that the "learning curves"

of the semiconductor industry would lower the costs of SSTV memory of this type much as the cost of pocket calculators has declined dramatically in recent years. This expectation has so far been borne out even more rapidly than initially hoped. The decline in the cost of the memory also facilitates the use of multiple frame memory techniques referred to earlier.

2) The standards are compatible with amateur radio equipment (at least at the lowest resolutions).

3) The scan of a new frame occurs by superposition of horizontal strips onto the old frame starting at the top and working down. This is a better match to our way of writing and permits transmission of just the top part of a picture much as one would "mask" off part of an overhead projector presentation.

4) Output is to a standard, unmodified TV set.

5) The intrinsically digital character permits straightforward amalgamation of data compression and various digital transmission techniques (even though transmission is currently done by analog conversion).

6) The digital computer-memory format permits straightforward change of scan and transmission rates which allows shorter delay times when higher bandwidth channels are available. This also allows format reconfiguration and trade-offs between resolution and gray scale and even color.

7) New advances in memory technology such as CCD devices can be straightforwardly assimilated.

<u>microprocessors</u>

Perhaps most exciting of all, the LANTEL development leads naturally into the incorporation of microprocessors into the system. The present circuitry can be considered in two categories: there is a memory (presently consisting of devices called MOS dynamic shift registers) and a system of control logic consisting of about 100 integrated circuits (IC's). Initially, the major cost of the solid-state SSTV system was the memory. Developments of use in the computer industry are reducing the cost of this component to where the cost is now dominated by the control circuitry (not so much the cost of the individual components but the expense of assembling and checkout). Incorporation of a microprocessor to do the control logic would enable one to substitute a small number of mass-produced chips for the custom assembly of 100 or so individual units. One would get the benefits of mass-production without having

actually to mass-produce a large number of SSTV units (that economy of scale will occur as well when the market develops). A present estimate is that about 35 IC's can be replaced with a microprocessor currently available for a few hundred dollars (and probably coming down in price). A new, faster generation of microprocessors has been announced which will permit replacement of perhaps all of the control logic.

An immediate benefit will accrue as soon as the incorporation of a microprocessor "breaks even". The flexibility of a device which can be programmed is enormous in terms of providing the voice-over-video capability, utilizing the memory and transmission time most efficiently according to the nature of the visual material, keeping track of transmissions and generally being "forgiving" of operator (i.e. teacher) mistakes. The introduction of even a slow microprocessor will permit the adoption of various data compression and image processing techniques to make pictures more efficient and to manipulate images for the benefit of the student. Essentially the whole realm of computer graphics becomes available via this telecommunications device.

In a sense, the incorporation of a microprocessor is an approach to an ultimate system. One may think of this as another avenue to arrive at the goal of a "smart terminal", widely believed to be a desideratum for dispersed data-processing systems. This development would also foster the marriage of telecommunications with CAI (computer-assisted-instruction). SSTV would then have the capability of providing remote access to a campus computer terminal. One lacuna in remote teaching might be filled in this manner. The provision of some sort of laboratory experience to students who are not on campus is a problem which does not admit of many approaches. One is to provide such experience through computer simulation of situations in the physical world with the remote student manipulating parameters much as he or she would do in the laboratory and observing what phenomena result. More work in developing teaching materials of this type is needed against the day when remote education is more of a reality --that day is not so remote.

The incorporation of microprocessors has obvious application in teleconferencing of various sorts and we have several times

mentioned the benefits of a telecommunications device of great general and universal utility. Economies of scale will reduce the costs to all, including education, the availability of terminals to talk to will increase as will the uses of each terminal and the increased familiarity will make the technique available to more people. We believe that this development will hasten the day when physicians will use SSTV for consultation with their colleagues, communication between their offices and their hospitals and continuing education to maintain their licenses to practice medicine (a trend to requirements of this sort may be discerned in many states). We see lawyers using SSTV to negotiate and modify contracts in consultation with colleagues in other states and also using it for continuing education in changing fields in the legal profession. High schools would use terminals for continuing teacher education as well as to provide students with a link to a university campus or to another school which might provide lectures or courses not available on campus. Once a terminal is available (and there are other terminals to communicate with), the possibilities for enrichment of even on-campus programs are myriad.

BARRIERS TO THE MILLENNIUM

Before we wax too enthusiastic about the potentialities of any technique, we must realize that things do not happen by themselves and that there are usually existing obstacles to progress.

The major problem is both educational and economic. People must be introduced to any new technique so that they may become familiar with it, with its merits and its disadvantages as well in order that ways to adjust to the latter may be found. In the field of education, students must be apprised of the possibilities of this kind of remote education and, that most conservative of all groups when it comes to their own area, teachers must be introduced to the potentialities of a new teaching ambience. The very desperation of the straits of many educational institutions may go some distance in making faculty attitudes more flexible and open to new ideas. That same desperation, however, also implies that we may not have too much time.

The various uses of SSTV must be developed so that private industry will see the potential market developing and push the process along by utilizing the economies of scale in mass-production.

A new technology without an existing market may require extra help and support from the governmental and foundation sector. The telephone company may be the logical place to start such technology or it may not because of possible disincentives which its regulated nature creates. It may be the case that the telephone industry, being regulated carriers, is allowed a return on invested capital (which means the telephone network) and would not benefit from increased utilization of the existing network.

The question of how widespread usage of SSTV would impact on the telephone system (and conversely) must be considered. Whether video signals in the audio range are closer to being data or voice communications is a question for the courts to decide at some point when the matter becomes pressing. The issue of protective devices for the telephone network is not a serious one since connection can be made via acoustic or inductive couplers or via approved hard-wired connections. The impact of an SSTV type call on local telephone service could be expected to be significant. Certainly the average length of a local telephone call would increase dramatically if SSTV transmissions become common. The present tariff structure,in which many localities provide almost unlimited time for a local telephone call without monetary penalty, might have to be looked at (there is already a trend in this direction). Not least of all, are there disincentives which exist which would cause the telephone companies to hinder progress of this technique? Would the orderly, planned expansion of the DDD telephone network be distorted by SSTV development?

Estimates by studies supported by the Department of Transportation indicate that telecommunications techniques could cause 7.5 million cars to stay at home each day instead of going to work and that almost a quarter of the work-related trips taken by white collar workers could be replaced by telecommunications While this must almost certainly be considered a good in terms of energy savings, one must not overlook possible dislocations in parts of the economy which might be affected (e.g. air transportation).

There are mundane practical problems which must be identified and sorted out before progress can proceed. There are at the moment no standards for SSTV. Only equipment used by radio amateurs is so configured that devices made by one manufacturer can communicate

with devices made by another. Standardization of the format and transmission parameters of a communications system is absolutely mandatory. A national conference and committee might well be formed to look into this.

Equipment development must be fostered in parallel with experimentation on the uses in education and in other fields so as to develop and disseminate needed techniques. As we have stated earlier, it is not clear whether the private sector is ready to take this task on as yet. The impact on the developing (broadband) cable industry must be assessed and due notice paid. Our thesis is that almost all of the non-entertainment uses of cable TV can be provided by SSTV and the existing DDD network. This should be subjected to searching scrutiny since, if true, it undercuts much of the argument based on social utility for public sector support of cable TV systems. Cooperation with the cable and broadcast TV industries would clearly be desirable because of the marriage which is possible via time-shared television utilizing narrow-band channels within a broadband channel.

In recent times we have become increasingly sensitive about the value of technological innovation. The "side-effects" have oftentimes appeared to have more negative effect than the innovation produced on the positive side. We submit that the safest innovation to encourage is one which merely enhances the efficiency of the individual and increases the range and nature of his interaction with others. We believe that SSTV belongs in the category of meritorious innovation but we should temper an excess of enthusiasm with some degree of caution. These are ideas whose time has come but it may also be the time for new ideas.

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